Rockfall risks along highways - Application of RHRS on a highway in the Serra do Mar mountain range (São Paulo, Brazil)

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1 INTRODUCTION

Highways bordering rugged mountainsides suffer with slope stability problems worldwide. Studying rock slope stability along highways is essential to propose prevention and mitigation measures and avoid that instabilities can cause harm to the local population and vehicles. Broadly speaking, the failure of rock slopes is associated with the presence of discontinuities, such as, joints, foliation planes and stratification. Geological and geomechanical models help to identify and describe these discontinuities.

Castilho et al. (2018) evaluated the risk to which users of a section of SP-055 Highway (Rio-Santos or BR-101) are exposed, in relation to collapsing of blocks from failures in the rock slopes. This highway stretch is located at São Sebastião city, northern coast of São Paulo State, Brazil. Critical slopes were defined by RHRS (Rockfall Hazard Rating System) (Pierson & Van Vickle 1990, Budetta 2004) index, to assist in finding priority slopes for future interventions on the highway.

The present work expands upon the author's previous work, combining the RHRS results with rockfall computer simulations. Rocfall simulations were carried out using cross sections obtained from topographical maps, allowing simulations from the entire hillside, while the RHRS indexes were obtained using field data, obtained from the slope area accessible from the road.

2 METHODOLOGY

The Rockfall Hazard Rating System (RHRS) is a method that assesses the risks involved in rockfalls on highways. The quantification of the risk is made taking into account not only the susceptibility of instability, but also the road characteristics, such as traffic volume, sinuosity, speed limit, slope distance from traffic lanes, roadway width. Other items that are analyzed are the height of slope, the size of the blocks, the region climatic conditions and the area rockfalls frequency.

To establish the risk index through RHRS, it was necessary to apply the SMR (Slope Mass Rating) system (Romana 1993), since this represents the parameter related to the local geology. Thus, other geomechanical classification systems were used, such as RMR (Rock Mass Rating) (Bieniawiski 1989) and RQD (Rock Mass Designation) (Deere, 1966).

The studied stretch, between km 115 + 840 m and 116 + 860 m, was divided into slopes, in order to prioritize stretches where there is already evidence of instability (fallen and rolled blocks that are currently lying near the highway). For each slope, a structural survey was carried out through the mapping of discontinuities present as fault, joints and main foliation planes. Kinematic analyzes were performed for each one of the slopes, aiming the identification of failures causing mechanisms. Simulations carried out in the RocFall 4.0 software (RocScience) allowed to establish the trajectory of the blocks detached from the slopes' faces and also of possible rolled blocks from uphill.

3 RESULTS AND CONCLUSION

The Kinematic analysis of the site showed that the foliation is the most problematic discontinuity for eventual instability conditions involving about 80% of the potential wedge failures and 70% of the planar failures. Risk analysis using the RHRS index concludes that between km 115 + 875 m and km 115 + 913 m, between km 116 + 390 and km 116 + 416 m, and between km 116 + 472 and km 116 + 607 m immediate stabilization measures are needed to prevent rock blocks from reaching the road. Such stretches indicate high risks to road users, so that a possible failure can cause physical and material damages to the population and vehicles. In total, in 32% of the analyzed section, some slope stabilization measures must be taken, and in 20% of the stretch, the remediation work should be immediate, which is very high considering the intense traffic of the road.

The Rocfall simulations added another layer of analysis on top of the RHRS results. In some cases, the RHRS indexes were confirmed and the simulations showed the rock blocks would indeed reach the road. On the other hand, some slopes with low or medium RHRS indexes showed simulations with rock blocks reaching the road. Although some diferences observed between the results of each method, the authors would like to emphasize that both methods are easy and fast to apply. With the combination of RHRS and Rocfall simulations, two methods of different purposes, an interesting and broad knowledge can be obtained, helping the highway authorities to take decisions that can save lifes.

KEYWORDS: Rockfall Hazard Rating System (RHRS), Geological Hazards, Slope Mass Rating (SMR), Rock Mass Rating (RMR)